CHAPTER 18

BRIDGE DECK SLABS

18.1 Design Criteria

The Department uses the load factor method of design as defined in the **AASHTO Standard Specification for Highway Bridges**. The design procedures in **AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications** shall be used with the approval of the Bridge Design Engineer. The design of the overhang shall also conform to Section, Cantilever Slabs, in the AASHTO Standards and meet the following criteria:

- Normal overhang is 2.25 ft.
- Maximum overhang is ½ of the beam spacing, or 4 ft., whichever is less.
- The designer must check the constructability of the overhang

18.1.1 Thickness

Concrete bridge decks shall be cast-in-place. Precast deck construction will be allowed in special situation with the approval the Chief Transportation Engineer. The minimum deck slab thickness will be 8½ in. The maximum is 10 in. Standard concrete cover in deck slab shall be 2½ in. for top reinforcement and 1½ in. for bottom reinforcement. Use of permanent stay in place (S.I.P.) forms will not be allowed; only conventional removable forms will be allowed.

The total thickness includes ½ in. for an integral wearing surface. The wearing surface is not considered a part of the working thickness. A ½ in. shall be deducted from the actual deck slab thickness in the design calculations for one course slabs as an allowance for depth of sawcut grooved finishing and wear. The superstructure design for bridges with one-course deck slabs shall include a 25-psf provision for a future 1 in. thick concrete overlay protective system.

NOTE: A one-course concrete deck slab construction is to be used for the design of deck slabs on all bridges except when approved otherwise.

18.1.2 Corrosion Protected Reinforcement in Deck Slabs

All concrete deck slab reinforcement steel shall be corrosion protected. All top and bottom layers of rebar in structural deck slabs shall be epoxy coated. These bars include transverse bars, longitudinal distribution bars, corner, skew, and header bars. In culverts where the top slab is used as a roadway-riding surface, the top layer of rebar shall be corrosion protected.

When galvanized reinforcement is considered, both the top and bottom mat layers shall be galvanized. In addition, chairs, tie wires, nuts, bolts, washers, other devices and miscellaneous hardware that is to be used to support, position or fasten the galvanized reinforcement shall be galvanized. Plastic chairs or plastic coated metal hardware, in lieu of galvanized components, may be used.

NOTE: The Designer shall designate the use of epoxy-coated reinforcement or galvanized reinforcement in the deck slab construction.

18.1.3 Slab Thickness and Reinforcement Steel

The following tables for one-course construction based on 2½ in. top cover, 1 ½ in. in bottom cover, and rebar perpendicular to traffic with f_c = 1600 psi and f_s = 24000 psi, has been prepared in order to establish uniformity in design and details. See Tables 18-A and 18-B below:

Table 18- A

ONE-COURSE CONSTRUCTION FOR DESIGN LIVE LOADING HS 20		
EFFECTIVE SLAB SPAN (S)	SLAB THICKNESS (Actual)	REINFORCEMENT STEEL (TOP & BOTTOM)
5’-9” to 6’-0”	8 ½ in.	#5 @ 7 in.
Over 6’-0” to 6’-3”	8 ½ in.	#5 @ 7 in.
Over 6’-3” to 6’-6”	8 ½ in.	# 5 @ 7 in.
Over 6’-6” to 6’-9”	8 ½ in.	#5 @ 7 in.
Over 6’-9” to 7’-0”	8 ½ in.	#5 @ 6 in.
Over 7’-0” to 7’-3”	8 ½ in.	#6 @ 6 in.
Over 7’-3” to 7’-6”	8 ½ in.	#5 @ 6 in.
Over 7’-6” to 7’-9”	8 ½ in.	#5 @ 6 in.
Over 7’-9’ to 8’-0”	8 ½ in.	#5 @6 in.
Over 8’-0” to 8’-3”	9 in.	#5 @ 6 in.
Over 8’-3’ to 8’-6”	9 in.	#5 @ 6 in.
Over 8’-6” to 8’-9”	9 ½ in.	#5 @ 6 in.
Over 8’-9” to 9’-0”	9 ½ in.	#5 @ 6 in.
Over 9’-0” to 9’-3”	9 ½ in.	#5 @ 6 in.

Over 9’-3” to 9’-6”	10 in.	#5 @ 6 in.
Over 9’-6” to 9’-9”	10 in.	# 5 @ 6 in.
Over 9’-9” to 10’-0”	10 in.	# 5 @ 6 in.

Table 18- B

ONE-COURSE CONSTRUCTION FOR DESIGN LIVE LOADING HS 25		
EFFECTIVE SLAB SPAN (S)	SLAB THICKNESS (Actual)	REINFORCEMENT STEEL (TOP & BOTTOM)
5’-9” to 6’-0”	8 ½ in.	#5 @ 6 in.
Over 6’-0” to 6’-3”	8 ½ in.	#5 @ 6in.
Over 6’-3” to 6’-6”	8 ½ in.	# 5 @ 6 in.
Over 6’-6” to 6’-9”	8 ½ in.	#6 @ 7 in.
Over 6’-9” to 7’-0”	8 ½ in.	#6 @ 7 in.
Over 7’-0” to 7’-3”	8 ½ in.	#6 @ 7 in.
Over 7’-3” to 7’-6”	8 ½ in.	#6 @ 7 in.
Over 7’-6” to 7’-9”	8 ½ in.	#6 @ 7 in.
Over 7’-9’ to 8’-0”	8 ½ in.	#6 @ 7 in.
Over 8’-0” to 8’-3”	9 in.	#6 @ 7 in.
Over 8’-3’ to 8’-6”	9 in.	#6 @ 7 in.
Over 8’-6” to 8’-9”	9 ½ in.	#6 @ 7 in.
Over 8’-9” to 9’-0”	9 ½ in.	#6 @ 7 in.
Over 9’-0” to 9’-3”	9 ½ in.	#6 @ 7 in.
Over 9’-3” to 9’-6”	10 in.	#6 @ 7 in.
Over 9’-6” to 9’-9”	10 in.	# 6 @ 7 in.
Over 9’-9” to 10’-0”	10 in.	# 6 @ 7 in.

The selection of beam spacings cannot be standardized since they depend on beam type. Generally, beam spacings of 8 ft. to 10 ft. are preferred. The basis for the selection of beam spacings shall include consideration of the necessity of future deck replacement and the maintenance of traffic associated with a deck replacement.

The main reinforcement shall be placed normal to the stringers regardless of the skew of the deck slabs. The bars shall be straight, continuous, and of the same size and spacing in top and bottom of slab. Reinforcement shall be #5 or #6 bars with a minimum spacing of 6 in.

Designers must locate stud shear connectors to avoid conflicts with the main bottom reinforcement spacing.
For continuous beam spans additional epoxy coated or galvanized longitudinal bars shall be provided over the interior supports. The reinforcement shall be designed in accordance with **AASHTO Article 10.38.4.3.**

The additional reinforcement bars shall be located between the distribution bars. In accordance with **AASHTO Article 10.38.4.4,** the additional longitudinal reinforcement bars shall be extended into the positive moment region that is beyond the anchorage connectors

The main reinforcement pattern in the acute corners of skewed slabs and in the deck slabs of curved girder bridges shall be given special consideration. In the acute corners of skewed slabs, some of the main reinforcement may have to be placed in a fanned arrangement extending into the corner of the deck slab. On curved girder bridges, the main reinforcement is generally placed radially.

This reinforcement shall also be corrosion protected; such as, epoxy coated or galvanized.

18.1.4 Haunches on Stringers

All steel stringer bridges with monolithic deck slabs shall be provided with a haunch over each stringer that is monolithic with the slab. The minimum depth of haunch shall be 1 in. at the centerline of the span. This is as measured from the top of the steel flange to the theoretical bottom of the slab at the center of the web. A deeper haunch may be required when the top flange exceeds 15 in. in width. This is to allow for deck slab cross slopes.

The minimum haunch dimension shall be calculated to include all factors such as roadway profile, architectural camber, camber for future overlay, camber for future utilities, deck cross slopes, etc.

Haunches of fascia beams of multispan bridges shall be set so that the top of the webs of fascia beams in adjacent spans line up.

The depth of the haunches shall be labeled on the plans only at the centerline of bearings. The depth of the haunch at the centerline of bearing is necessary on the plans to enable the contractor to verify the concrete seat elevations. After the superstructure steel has been erected, the Contractor will compute the depth of the haunch at other locations along the span.

Haunches to a maximum of 4 in. shall be reinforced with U-stirrups. The minimum reinforcement shall be #5 stirrups at 12 in.

Where field splices in the stringers are shown on the plans or permitted in the Specifications, the haunch shall be a minimum depth of 1 in. over the splice plate. A 1 in. minimum clear cover shall be maintained between the main steel reinforcement and the bolts.

18.1.5 Concrete Placing Sequence

The superstructure design must be evaluated to determine the need for a pouring sequence. The designer should consider the effect of the plastic concrete on the girders in evaluating the need for a pouring sequence. The designer must consider beam or girder deflection in developing the pouring sequence. Normally, deck concrete placement for continuous spans begins at the low point on the deck and proceeds up grade. However, the Designer shall determine the pouring sequence of the slab. Often, where the deck grade is minor, the pour may commence at either end.

The contractor may be permitted to pour the deck continuously with approval of the Bridge Design Engineer. Any deviation from the pouring sequence must consider beam or girder deflections.

A concrete deck slab placing sequence shall be shown on the plans for deck slabs supported by trusses, arches, and continuous and cantilevered design. Other types of structures may also require special deck placement sequences such as single span curved girder bridges.

Details of the transverse construction joints for the deck placing sequence should be developed and shown on the plans. The joint shall be keyed and the entire face of the joint shall be coated with an approved epoxy-bonding compound.

Designing the construction joint as an edge beam must be considered. For skewed spans, a skewed-stepped arrangement may be required.

In the construction of Integral Abutment deck slabs, if girder continuity is provided, a deck placing sequence should be detailed for spans greater than 100 ft.

18.1.6 Machine Finishing

It is generally accepted that finishing machines produce more durable and better quality decks. Make every effort to eliminate adverse geometrics from bridge decks during design phases so that finishing machines may be used.

When the concrete or concrete overlay protective system on the deck surface has cured for a minimum of 14 days and has reached strength of at least 4000 psi, transverse grooves shall be sawcut into the surface of the bridge deck. Requirements for the sawcutting operation are given in the Standard Specifications.

Grooving of skewed bridge decks shall not be overlapped. Grooving passes on curved decks shall be made radial to the center of the curve with ungrooved gores at the outside of the curve. If the curve is such that the width of the gores exceed 4 in., the first pass of the grooving machine shall be normal to the center line of the span at midspan with subsequent passes parallel to the initial pass.

18.2 Finished Deck Elevations

The designer must include the framing plan and camber diagram for each span, as line drawings, in the plans. Finished deck elevations are shown in the plans, at the centerline of bearing over each abutment and pier line, and at $1/10^{th}$ points or at 10 ft. intervals, whichever is less:

- Transversely over each beam
- Longitudinally along the span at the break points in the cross slope of the deck

18.3 Approach Slabs

Approach and transition slabs are required for all bridges on the DDOT Highway System. The end of the approach slab shall be parallel to the skew. The width is from fascia to fascia of the bridge.

The end of approach slab should rest on a sleeper slab to prevent from moving excessively. The excavation for the sleeper slab shall be made after the compacted abutment backfill is placed. The sleeper slab shall be founded on undisturbed compacted material. No loose backfill shall be used. Approach slabs shall always be a separate pour from the superstructure slab and placed on an aggregate base.

18.4 Approach Slab Design

Generally, fill placed behind abutments settles after the bridge is opened to traffic. For this reason, the Department's policy is to construct reinforced concrete approach slabs to span the fill area.

The approach slab shall be designed as a structural slab minimum of 15-in. thickness that is supported at each end. Their lengths shall vary from a minimum of 20 ft. to a maximum that is based on the intercept of a 1 on 1 line from the bottom of the abutment excavation to the bottom of the approach slab. The slab shall be designed for nearest to the following span length. This length is to be measured along the centerline of roadway.

18.4.1 Reinforcement in Slab

- Span length = 20’ – 0”
  - Slab Thickness = 1’ – 3”
  - Top Longitudinal Bars # 5 @ 12 “
  - Bottom Longitudinal Bars # 7 @ 6”
- Span length = 25’ – 0”
  - Slab Thickness = 1’ – 3”
  - Top Longitudinal Bars # 5 @ 12 “
  - Bottom Longitudinal Bars # 8 @ 6”
- Span length = 30’ – 0”
  - Slab Thickness = 1’ – 3”
  - Top Longitudinal Bars # 5 @ 12 “
  - Bottom Longitudinal Bars # 9 @ 6”
- All transverse top bars shall be # 5 @ 18” and bottom bars # 5 @ 9”
- Concrete cover for top Longitudinal Bars = 2 ½ “
- Concrete cover for Bottom Longitudinal Bars = 3 “

NOTE: Approach slabs will always be required for integral abutment bridge structures. Special provisions shall be made to allow free movement of the approach slabs if curbs or barriers are present.

18.5 Medians

Unless precluded by profile and geometric considerations, the median area between parallel bridges shall be “decked over” when the width between curb lines is 30 ft. or less. When the median width is greater than 30 ft., cost estimates shall be made for the alternative of “decking over” vs. ”open well design”. Decking over is preferred in all cases for safety reasons when the extra construction cost is relatively insignificant. Live load design for the median area shall also be HS20+25 percent (HS25).

18.6 Parapets, Barriers and Sidewalks Joints

- Provide a ¼ in. open deflection joints in parapets at intervals not exceeding 20 ft. Contraction joints at the midpoint between the open joints shall also be provided.
- Contraction joints shall be provided in sidewalks at the locations of the 1/4 in. open parapet deflection joints.
- Provide a ¼ in. open deflection joints in median barriers at intervals not exceeding 15 ft. There shall be no contraction joints between the open joints and no contraction joints located below the open deflection joints.
- Full depth joints shall be provided in parapets, median barriers and sidewalks at locations of transverse Expansion and Fixed deck joints. The full depth joint opening width shall equal the transverse deck joint opening width.
- All reinforcing steel in parapets, median barriers and sidewalks shall be corrosion protected, such as, epoxy coated or galvanized.

18.7 Longitudinal Bridge Joints

Longitudinal joints in bridge decks may be required for very wide bridges, widened bridges or stage-constructed bridges. Longitudinal joints are always placed between beams or girders. Place them in the median, if possible. Avoid placing longitudinal joints in the wheel path of vehicles or travel-way because of the hazard to motorcycles. Compression seals are not used for longitudinal joints. The designer must determine the amount of joint movement, both transverse and vertical, when designing longitudinal strip seals.

Longitudinal construction joints shall only be provided where necessary for stage construction and for compatibility with the deck slab pouring sequence on wide structures with many lanes, or where necessary to accommodate transverse expansion on wide structures (i.e., generally for superstructures wider than 88 ft. The joint shall preferably be located beneath the median barrier.

18.8 Construction Joints

Construction joints, either transverse or longitudinal, are permitted only at locations shown on the plans. A construction joint must be used at the break between pours, such as those required by the pouring sequence. Normally, construction joints are keyed, cold joints.

18.9 Bridge Joints

Bridge designs must allow for movements due to temperature. Both steel and concrete structures expand and contract because of temperature changes. Refer to Section 3.16, Thermal Forces, in the **AASHTO Standard Specification for Highway Bridges**. Use moderate climate temperature range for the District area.

18.9.1 Fixed and Expansion

Joints are constructed in bridges to accommodate movement (rotation, expansion and contraction). All joints must be sealed to prevent leakage of water onto the bearings and substructure. Obtaining a watertight bridge joint is a difficult objective over the life of a bridge. Efforts should be made to reduce the number of deck joints on the bridge.

Transverse Joints at fixed bearings are designed to accommodate movements of the span due to rotation of the bearing caused by the loading. Transverse Joints at expansion bearings are designed to accommodate expansion and contraction movements of the span caused by temperature changes and loading. The two types of joints used by the Department at expansion bearings are:

- Strip seals
- Compression seals

Transverse deck joints on most new bridge decks (i.e. joint movements up to approximately 4 in.) should consist of either preformed elastomeric compression seals or glandular type strip seals. The use of bolt-down armors attached to structural steel, hooked bar anchors into concrete and strip seals type join is recommended on projects involving deck joint reconstruction. Modular type deck joints are recommended for joint movements in excess of 4 in. To protect the concrete slab, all deck joints shall have steel armoring on the edges. This shall include deck joints on bridges that are to be rehabilitated or reconstructed. Compression seals smaller than 2½ in. are generally recommended only for fixed end joints. Payment for structural steel rails, shapes, plates, etc., used in deck joints shall be included in the linear foot price bid for these items.

18.9.2 Strip Seal Expansion Dams

In selecting strip seals, the designer must consider the relationship between total movement, minimum and maximum joint widths, and installation temperature. Strip seal expansion dams shall consist of a molded neoprene rubber gland locked in the cavities of two parallel steel rail sections. The steel rail material shall conform to **AASHTO M 270/M 270 M Grade 250 or AASHTO M 270/M270 M Grade 345W**. The entire joint system shall be hot dipped galvanized after fabrication.

Any galvanized coating of the deck joint system that is damaged during field welding or from other causes shall be repaired by methods outlined in **ASTM A780**. Unless specified, the galvanized surface should not be painted. If painting is required, refer to DDOT standards for guidance in repairing the damaged area. The damaged area shall be repaired prior to installing the neoprene gland. The neoprene gland shall be continuous for the full bridge width including sidewalks, parapets and median barriers.

Strip seal expansion dams will be used when the following conditions exist:

- When the length contributing to expansion is less than 65 ft. and the skew is greater than 35 degrees.
- When the length contributing to expansion is greater than or equal to 65 ft. and less than or equal to 250 ft., and the skew is greater than 25 degrees.
- In the area outside of the 4 in. wide sealer limit on skews less than or equal to 25 degrees.

NOTE: Special consideration shall be given when the length contributing to expansion is greater than 250 ft.

When a transverse strip seal intersects with a longitudinal compression seal, the joint subjected to the larger movement shall remain continuous and the other seal shall butt up against it. When longitudinal and transverse strip seals intersect, various factory-molded intersections are available as needed. It is recommended that strip seal manufacturers be contacted in order that the most effective details can be specified for these situations.

It is essential to the operation of the strip seal that no form of hot or cold applied joint filler be placed over the top of the rubber gland. All sidewalk joints must have steel cover plates. Joints in parapets and median barriers should preferably, if possible, be designed without steel cover plates. In these cases the steel rail sections shall be angled up into the parapet or median barrier and the concrete tapered to the edge of the rail as required.

When approved, steel cover plates may be used if required on highly skewed structures or for specific project requirements.
The maximum allowable joint width measured normal to the steel rail sections shall be 4 in., with 3 in. preferred. The minimum joint widths shown on the construction plans for the superstructure shall be set at 70 deg. F. They shall be set, based upon the project requirements and the minimum installation width of the seal, normal to the steel rail sections

The minimum joint installation width is generally equal to 1½ in. for smaller size strip seals.

The designer should closely analyze and provide details and configurations in problematic areas such as, sidewalks and parapets. The potential for joint leakage is usually greater in these areas, and they are often difficult to construct and maintain.

Joint details at sidewalks, parapets and median barriers shall be shown on the plans. The joint anchorage into the deck should be designed with a factor of safety of at least 2.0. To assure that this element of the joint will not fail, the factor of safety should be applied to all known loads.

18.10 Deck Drainage

The bridge deck drainage system includes all drains located on the bridge deck and the means used to convey the water collected. A structural analysis may be required on all bridge components modified to accommodate the bridge drains. Girder spacing may need to be adjusted or adjust the drain locations due to the proximity of bridge rail posts. The station and offset of each deck drain shall be specified in the plans. Drainage from structures shall not drip onto bearings, pier caps, abutment caps or pedestrian walkways.

18.10.1 Hydraulic Criteria

The hydraulic design frequency shall be 5 years and the maximum spread width shall not encroach into the through lanes.

18.10.2 Cross Slopes

The cross slope on a bridge deck shall be a minimum of 0.5 percent and should match the roadway on both sides of the bridge deck for a smooth transition.

18.10.3 Grades

Bridge decks require adequate grade for proper drainage. This will ensure that chlorides drain off the bridge deck and will prevent ponding and freezing of water. In addition, proper drainage prevents hydroplaning on decks with little surface texture. Provide a minimum grade of 0.5 percent on bridge decks. If the longitudinal grade is less than 0.5 percent, additional drains or special sloping of the gutters may be required.

Sag vertical curves should be avoided on bridge decks for hazards from flooding and icing, and aesthetic reasons. In order to have adequate longitudinal drainage near the high point of vertical curves, the grade shall not be flatter than required for sight distance requirements.

18.10.4 Inlets/Scuppers and Downspouts

Generally, the number of inlet bridge drains should be kept to a minimum. Bridge drains generally become a maintenance problem in future years. Bridge scuppers should not create a hazard to bicycle users.

- Since drainage systems are more susceptible to blockage by debris, only the Department's approved system will be used.
- Bridge drains are generally not recommended on structures less than 400 ft. long if they have full width shoulders, adequate cross slopes and have adequate catch basins on the bridge approaches unless adverse geometric considerations dictate.

Structures that do not have full shoulders will require bridge deck drains at more frequent intervals as determined by design calculations for the allowable spread of 6 ft. From a practical standpoint, deck drains should be placed near and up slope from expansion joints on the bridge deck to keep storm drainage out of the joints and away from bridge members.

Bridge drainage systems over streams shall be located midway between diaphragms or cross frames and shall not be discharged directly into the stream an. Drainage directly onto unpaved embankments or natural ground where erosion could undermine structural elements will not be permitted.

Bridge drainage systems over land shall avoid horizontal runs of drainpipe if a reasonable modification to the design scupper spacing permits the placement of drains adjacent to piers at the low end of spans. Scuppers shall not be discharged on embankments or any traveled way (either vehicular or pedestrian). When applicable and feasible, drainpipe shall be hidden from the view of oncoming traffic.

Long runs of outlet pipe on flat grades shall be avoided. Where horizontal runs of drainpipe cannot be avoided, the minimum pitch shall be 8 percent.

Drainage from bridge superstructures or embankments shall not discharge on or across a railroad ROW, National Park Lands and other private properties without their approvals.
Downspouts, where required, shall be fabricated from galvanized steel alloy pipe or fiberglass pipe and shall have a minimum diameter of 8 inches. No painting of the galvanized steel alloy pipe is required. Pipe shall be provided with readily accessible cleanouts and shall be located such that no water is discharged against any portion of the structure. The

pipe shall discharge into a drainage system that conducts the water away from the structure.

Downspouts shall be located so as to facilitate their discharge away from traffic. Downspouts shall not be cast in the inside of or within any substructure limits.

NOTE: Bicycle safe grates shall be used for all inlets. Grates and covers should be located in such a manner that minimizes severe and/or frequent maneuvering by the bicyclist.

18.10.5 Catch Basin System at Bridge Ends

Unless cross-slopes or superelevation preclude flow on one side of the roadway, any bridge that is on a grade or in a sag, where it may collect highway drainage, should have catch basins provided just off the upgrade end of the bridge in each gutter.

Inlets placed up slope of the bridge must be designed and placed to intercept 100 percent of the approach flow using the return period selected for the roadway system. Most bridge drainage systems are marginal, and additional water from the approach roadways should not be imposed on them.

Water should be prevented from running down a crack at the paving notch and undermining an abutment or wingwall. A similar nuisance is created when water runs down a median strip, between parallel roadways and parallel bridges, and washes out the slope paving underneath.